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GUM DISEASE OF CITRUS TREES IN CALIFORNIA.

By RALPH E. SMITH and O. BUTLER.

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GUM DISEASE OF CITRUS TREES IN CALIFORNIA.

By RALPH E. SMITH and O. BUTLER.

INTRODUCTORY.

The most common and characteristic citrus tree diseases in California are those which may be included under the general term "Gum Disease." Although the troubles which we shall consider are known locally under a variety of names, they all have the one feature in common of an abnormal production of tree gum from the affected parts, and so may be included in the same category. As we shall show at the proper time, this characteristic of gumming is not the only one common to these various troubles.

To a certain extent the various forms of gum disease are serious, and yet they are by no means disastrous; their nature is in a sense unknown, and yet for practical purposes fairly well understood; their control is often difficult and by no means generally accomplished, yet almost always successfully attained when taken in time by proper means, when conditions impossible of improvement are not present. In short, gum disease is one of those conditions which require careful, continued, intelligent work along various simple lines for successful handling, rather than something of a strikingly specific nature with quick evidences of action and effect. It is also easier of prevention than of cure.

The present bulletin will consider the various citrus troubles which may be included in the category of gum diseases, showing the features which they have in common and discussing their nature, together with methods of prevention and cure. Since the founding of a laboratory of plant pathology in southern California opportunity has been afforded for a thorough study of the gum disease problem in the field and laboratory under the most favorable conditions. At the same time many growers and other interested persons have been experimenting in a variety of ways in the practical treatment of the disease, so that a considerable fund of information is available, based on the experiences of others. This is freely drawn upon in the present bulletin.

From our own field work and the observations of others, taken in connection with the laboratory study which we have made, we feel ready to speak with a considerable degree of certainty upon the subject. Further studies are still desirable and are being carried on from the standpoint of advanced plant physiology and pathology as to the exact nature of the influences and processes which bring about the characteristic effects of gum disease.

ANATOMY AND PHYSIOLOGY OF THE CITRUS TREE.

This account of gum disease is based on the belief that no parasitic or infectious organism is primarily concerned in causing the trouble, but that the various forms of the disease are the result of physiological disturbances in the functions of the tree. A clear understanding of

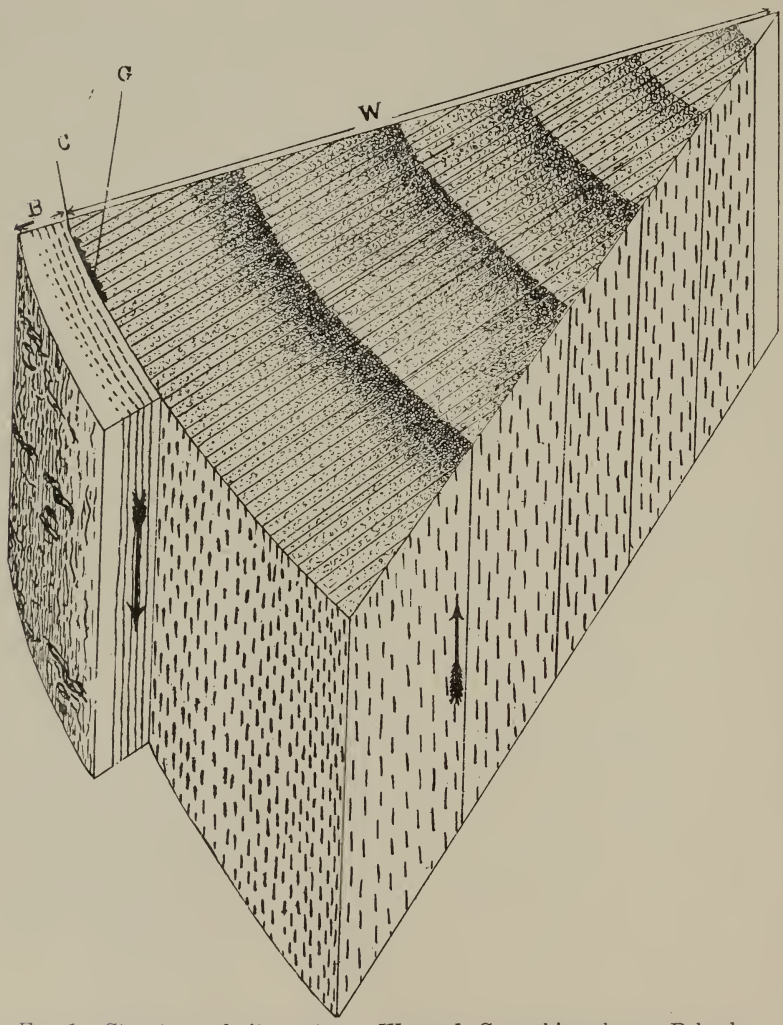

FIG. 1. Structure of citrus stem. W wood, C cambium layer, B bark, G region of gum formation. Arrows indicate upward flow of sap in wood and downward path of nutritive material in bark.

the principles of plant physiology and structure is therefore necessary to a proper conception of the nature of the disease.

The citrus tree, like other similar plants, consists of certain parts, of which the most important in the present connection are the root, stem and branches, and the leaves.

The Root.—The root is the organ of absorption of water and mineral food elements, and likewise acts mechanically in holding the plant in the soil. It subdivides extensively, resolving at its extremities into the finest hairlike branches and outgrowths. Through the root is obtained water from the soil, with nitrates, phosphates, potash, iron, lime, etc., in solution, by a process of absorption. All the water used by the tree is obtained in this way from the soil.

Upward Flow of Sap.—This watery solution or crude sap passes into the woody portion of the root and thence travels up into the trunk, the stream being located mainly in the younger, outer part of the wood or sap-wood. There is no rapid flowing along of this water up into the tree from the root, like the blood circulation of animals. The current is a considerable one, however, particularly in the citrus tree, and the sap passes through certain comparatively large tubular pores or vessels in the wood, which are formed for this purpose. Citrus trees are particularly quick to respond to the application of water to the roots, sending large amounts up through the trunk very soon after the application is made.

The Leaves.—While the root is engaged in absorbing and pumping up water and mineral salts, the leaves are equally active in doing their part in the nutrition of the tree. During sunlight the leaves constantly absorb carbon dioxide gas from the air, and, by a remarkable activity which they possess, they decompose this gas and unite its carbon with the hydrogen and oxygen derived from the water furnished by the roots, forming starch. In this way the green leaves of plants accumulate large amounts of starch during the daytime and are charged with this substance when evening comes.

Digestion.—Starch being a solid material, it is necessary that it be made soluble before it can pass out of the leaves or be further utilized by the plant. This process takes the place in the same manner as in animals, namely, by the action of the substance called diastase, which converts starch into sugar and thus makes it soluble in water. Further changes of a very complicated nature then go on in the nutritive materials, through which a combination is effected of those materials obtained respectively by the roots and leaves, forming various soluble substances of a nutritive nature.

During these changes most of the water taken up by the roots is carried up to the leaves, and this process constantly goes on, even in the tallest trees. A constant and abundant flow of crude sap takes place, passing through the outer layers of wood, as previously described, dividing and subdividing into the various branches and twigs, and finally reaching the leaves. At the same time all parts of the tree

absorb more or less of the soil water, by its movement in all directions, sufficient to prevent wilting and drying out.

Downward Flow of Sap.—After the nutritive material has been properly prepared as described above, it is distributed again to all parts of the plant, in the form of a solution in water. This distribution takes place mainly by a current passing through the inner bark, and thus we have in the trunk, to a certain extent, two currents of sap moving in opposite directions, one going upward through the wood, carrying crude food material, and the other coming downward through the inner bark, furnishing digested material for the growth and nutrition of the tree. The latter process, however, does not consist in an abundant flow of sap traveling rapidly in one direction, but is rather a slow process of absorption and diffusion of the nourishing materials.

Cambium Layer.—Just between the bark and wood is situated the most vital part of the tree, the cambium layer, which is the seat of growth in thickness. This area, consisting of a narrow layer of tissue running around the trunk and all the branches just between the wood and bark, gradually grows out with the expansion of the tree, forming the elements of the wood on its inner side and those of the bark on the outer side. To the cambium goes, therefore, much of the digested food material, and it is used in the formation of the tissues mentioned, just as the blood in animal life conveys nutritive matter for utilization in the growth and maintenance of the various tissues of the body.

The account here given is but a brief one, and does not consider all the numerous and obscure processes which go on in the formation, movements, and chemical changes of these food materials. Enough has been said, however, to show the extremely complicated and delicate nature of the process, and the fact that in plants, as well as in animals, complications of the nature of indigestion and other failures or abnormal effects in the vital processes may easily occur. This is particularly the case in the citrus tree, which is of a very susceptible nature with an abundant flow of sap, and is grown in California under decidedly artificial conditions, with the supply of moisture and nutriment largely controlled by the grower rather than by favorable influences of nature. Processes of oxidation, respiration, excretion, and other complicated chemical and physiological changes also go on in the citrus tree, and these are easily affected, adversely or otherwise, by climatic, soil and cultural conditions.

GENERAL NATURE OF GUM DISEASE.

Gum disease or *Gummosis* of trees is a term applied to a condition in which an exudation of gummy sap takes place through the bark. Such a flow of gum may be accompanied by other symptoms more or less pronounced, and is almost always connected with a dying or unhealthy con-

dition of the tree. In other words, the gumming is a symptom of injury or disease and not a normal function. Such troubles are particularly characteristic of two classes of trees: citrus and stone fruits. Gumming in the cherry, peach, plum, or apricot is even more common than in the orange or lemon.

Causes of Gumming.—The production of gum in these trees has been held by some authorities to be always caused by mechanical injuries. Cases where gumming occurs and no injury can be found they attribute to some former injury, the effects of which become evident only after the wound itself has disappeared, or to an injury situated at some distance from the point where the gumming occurs. It is evident that injuries often do start gumming and that this is greatly increased by a plentiful water supply at the roots; but that the latter in excess, or some other physiological disturbance, may actually cause as well as accelerate gumming is not so generally recognized. That such is the case, however, can scarcely be doubted from California experience. Many instances occur and some fairly characteristic diseases in which violent disturbances in the physiological processes, as well as some in which these changes are not violent but extremely obscure, result in serious injury to the vitality of the plant, accompanied by various forms of gumming from the affected parts.

In the sour-sap disease of stone fruits, for instance, supposedly caused by a sudden change from vigorous, unseasonably early activity to a period of dormancy produced by the occurrence of cold, rainy weather, abundant gumming occurs on the affected trees or branches. Gum pockets are often formed on cherry trees in wet spring weather on sound, uninjured branches. In the peach profuse gumming occurs in wet weather on twigs affected by the blight fungus (*Coryneum beyerinkii*), but in the same tree gumming is a common effect when injured by unseasonably warm winter weather or other effects not of a parasitic or mechanical nature. That the same is true of citrus trees admits of no doubt. Gumming is an indication of something wrong. The effect is distinctly pathological and not normal. It takes many different forms and some very characteristic ones, varying with the species of the tree and the conditions which cause the trouble. The disease does not, however, require the occurrence of a parasitic organism or mechanical injury to account for its appearance. Nor can cause and effect always be closely identified, for the place on the tree and the time of gum formation may show no evident connection with the cause, and the cause itself may be very obscure, since these trees are peculiarly liable to functional derangements in which the exact conditions which produce them and the exact manner in which they come about are most difficult of determination.

Place of Gumming.—The point where the gumming breaks out in these cases, where no infection by a parasite and no mechanical injury is involved as the original cause, depends entirely on local conditions in the tree, its specific peculiarities, the condition of its tissues, and other individual factors. If the exciting cause is one of climate, soil, or moisture conditions, usually the whole tree is equally affected. With the tendency to gumming excited, the actual outbreak occurs at the point of least resistance, which may be near an injury, recent or old, at a place having relation to the point of budding or of the giving-off of branches, or at places in the tree where for some reason the structure of the tissues is in a condition to produce irregularities in the flow of sap or other functions. The case is almost entirely analogous in this respect to the condition of a person affected by ulcers, boils, or similar outbreaks. Back of the visible effects is a deranged condition of some vital function or organ, the result of which shows itself as a superficial eruption or other effect at the point on the body which for some local cause is most susceptible.

The lesion thus produced may then by infection or processes of decay and irritation persist and increase, even after the original causative condition has disappeared. A similar conception is justified in regard to the various peculiarities in the visible appearance of gum disease. The lesions, ulcers, or affected areas produced are not primarily the seat of the trouble. They represent rather the effect of what may be called a general constitutional derangement showing itself by external outbreaks or symptoms at whatever points may chance to be most susceptible.

Physiological Diseases.—That such constitutional derangements producing the so-called physiological or autogenous diseases occur in plants the same as in animals and even without the occurrence of any radically unfavorable or injurious conditions to account for them, is evidenced by such troubles as Beet "Curly Top," "California Vine Disease," and the Aster "Yellows." In all these cases what may be called a primary weakness exists back of the visible symptoms, and in this weakness can be sought the fundamental cause and nature of the disease. It is, therefore, not necessary to identify a parasite or strikingly evident climatic or soil conditions to account for diseases of this class.

All Trees Not Affected.—The question is often asked, Why, if climatic, cultural or similar conditions of some sort produce the ordinary forms of citrus gum disease, all trees in the grove growing under practically identical conditions are not similarly affected? Why is one tree completely covered with scaly bark and those on every side of it entirely free from the disease? This is explained by the same reason that all

the trees in the peach or apricot orchard do not take sour-sap alike or all the beets in the field have curly top. Also that all men do not take cold or indigestion when exposed to exactly similar conditions. Trees like persons have individuality. No two are in exactly the same condition or respond exactly alike to the same influences. The exciting cause tending to produce gum disease may act exactly alike upon all the trees in the orchard, but affect them in various degrees. Some may be not at all affected, some influenced to a certain extent, but finally pass the critical stage without visible effect, while in others the influence is too great and external outbreaks occur.

In citrus trees gumming, on the whole, has more characteristic and definite forms than in the stone fruits. For this reason diseases of this nature, which are abundant wherever citrus trees are grown, have received various distinguishing names according to the various manifestations of the trouble. An examination of the literature of citrus culture shows that in every citrus growing district of the world gum disease plays a prominent part, though the form taken by the malady varies to a considerable extent.

GUM DISEASE IN CALIFORNIA.

Under the general term "gum disease," as comprehended in this bulletin, we include all the more definite troubles with citrus trees in California in which the exudation of gum takes place.

Gum Disease Not Infectious.—It may be said here without extended discussion that in no case have we been able to recognize or demonstrate the presence of any fungus, bacterium, or other parasitic organism as the cause of any form of citrus gum disease. This phase of the matter has received very careful attention at the Whittier laboratory during the past three years, and from the very numerous cultures and microscopic examinations which have been made without finding any indication whatever of any such parasite, we feel safe in concluding that the diseases hereafter described are of a physiological or autogenous nature, brought about by a deranged condition of the tree itself. This conclusion is based on a very large amount of careful work, and coincides with the results of much observation in the field as to the probable nature of these diseases, as well as the experience of many practical growers. The appearance and occurrence of the diseases is not such as to point to parasitic infection as the primary cause when the matter is closely followed up.

GUMMING FROM INJURIES.

The tendency of citrus trees, as well as those of the stone fruits, to form gum when mechanically injured is readily demonstrated by experiment. If the trunk of a citrus tree is injured in almost any manner, either by bruising, pounding, or by the application of acid or any injurious substance, gumming frequently results. The flow of gum may not be confined entirely to the point where the wound is made, but often an irritation is produced which is transmitted to a considerable distance and the gumming spreads up the trunk. Cases are not infrequent in fumigation where sulphuric acid or the residue from the combined acid and cyanide of potash is poured against the trunk of the tree or upon the main roots, and the side of the trunk up to a considerable height, far above the point where the liquid was applied, is injured and breaks out in gumming. No definite disease can be described as a result of injury, but the gumming produced in this way is well known and very suggestive.

LEMON GUM DISEASE OR GUMMOSIS.

The term *Gummosis,* if it be applied to any one specific trouble, may be best given to the disease now under consideration. While commonly distinguished as the gum disease of the lemon, the characteristic trouble is not confined to lemon trees, and therefore a name which suggests this limitation is not well chosen. We therefore suggest the specific use of the name "Gummosis" for reference to this form of disease. Gummosis is characterized by a breaking out of gummy sap on the trunk of the tree, from the point of budding up to a rather limited height. The exudation of gum commonly stops abruptly at the line showing the place where the tree was budded. It has little tendency to run down into the roots, nor does it in typical cases spread up into the branches or even high on the trunk. In the most characteristic form of the disease the breaking out of gum takes place for only a short distance above the crown of the tree.

Not Florida Foot-rot.—In two respects the disease differs decidedly from the usual foot-rot of Florida and Europe; it does not affect the root or cause a decay of the bark.

Closer examination shows that the gum does not originate in the bark, but breaks out through the latter by mechanical pressure from within. If the bark is removed from the affected area, it is found to be separated from the wood to a considerable extent, and the cambium layer just between the bark and wood, as well as the inner bark and outer portions of the wood, is discolored and more or less affected. The area affected may be large or small, according to conditions, or may continue

to spread around the trunk until the tree is completely girdled. In severe cases the bark of the affected portions dies and the tree itself may do the same.

In this form of disease there is little or no indication of any abnormal growth of the bark, such as scabbing or scaling, but simply a breaking through of the gummy sap from within by mechanical pressure. An-

FIG. 2. Gummosis of lemon.

other characteristic effect of this trouble is an abnormal setting of the fruit by affected trees, together with premature maturity. Trees badly affected are always covered with a large amount of prematurely ripe fruit, showing in lemons a bright yellow color while still small. Gummosis has been much more prevalent in wet years than those in which the winter rains were in small amount. This relation of a large amount

of soil moisture is prominent in every way, both as regards rainfall and irrigation.

The effects of gummosis in the orchard have been very severe in many groves, particularly with lemons. Many trees have died, and in some orchards a large portion of the acreage has been lost or severely injured.

Relation to Soil and Location.—The occurrence of this form of gum disease is very manifestly connected with certain conditions of soil and location. It is almost invariably seen in trees growing in poorly drained situations, at the lower end of orchards situated on a slope, in places where water frequently stands about the trees, in heavy soils or in trees which have become too deeply buried by washing down of soil in irrigation. Most commonly the disease comes about from improper conditions

FIG. 3. Lemon grove, with portion in foreground destroyed by gummosis.

regarding soil moisture, yet this can not be made an absolute rule. When such is not the case, however, it is almost invariably true that the trees are too deeply buried, the trunk above the point of bud union being surrounded with earth. In cases where this earth is of a clayey or heavy nature, packing closely about the trunk, and particularly, as is the usual case, if it is not disturbed by cultivation, but allowed to become hard and dry, the condition is aggravated and the liability of gummosis becomes greater.

The conditions enumerated are most apt to occur at the lower end of an orchard where the water, together with the soil and silt which it carries, tends to accumulate. For this reason, as stated above, the worst cases of gummosis and the majority of affected trees in orchards situated on a slope are found at the lower end. Occasional instances occur where the disease seems to develop in light gravelly soils or in

places other than the lower end of a slope, but such cases are due very largely to a surface deposit or wash of gravel overlying a hard, heavy soil. In the case of a leaky ditch or flume running through or by the orchard the trees in that vicinity are the most likely to be affected with gummosis.

A form of gum disease similar to this is also easily produced by heaping material such as manure, weeds, or green cover crop close about the trunk of the tree. Occasionally, in applying such material, it becomes piled about the trunk, and this often leads to gummosis.

This description of the character and occurrence of gummosis, or lemon gum disease, will be sufficient to give a correct idea of the form of disease which we mean to include under this heading. A description of its more intimate nature, together with consideration of means of relief and control, may now be taken up.

EFFECT OF GUMMOSIS UPON THE TISSUES.

The flow of gum from the trunk of trees affected with this disease, occurring as it does most abundantly under conditions of excessive moisture, is often thought to be simply a breaking out of the sap by mechanical pressure on account of its excessive amount. This, however, is not strictly the case. As has been previously mentioned, the gum itself is a pathological product and not a normal constituent of the sap. A microscopic study of the condition of affected tissues has been made during this investigation, and while it need not be reported on at length in a bulletin of this character, something may be said as to the real nature of the process of gum formation and exudation. In our brief description of the anatomy and physiology of the citrus tree we have called attention to the structure of the trunk and mode of action of the sap in the same. We pointed out that in the outer part of the wood a vigorous flow of water is passing upwards to the leaves. This water also is absorbed laterally to some extent sufficient to keep the trunk and bark full of moisture. Meantime, the prepared food material is coming down through the inner bark and much of it passing to the cambium layer, where it is used in forming new tissue. On the inner side the cambium normally keeps laying down new layers of wood so long as growth is active. In other words, there is a constant deposit of new wood on the outside of that already formed. This is accomplished by the constant transformation of the cambium layer cells into wood cells, by a deposit of thickening layers of cellulose upon the originally thin and delicate walls. It is just in this process that the actual gum formation takes place. The material which ought to go to form the thickening of the wood cells stops short of this change and turns into gum, which is

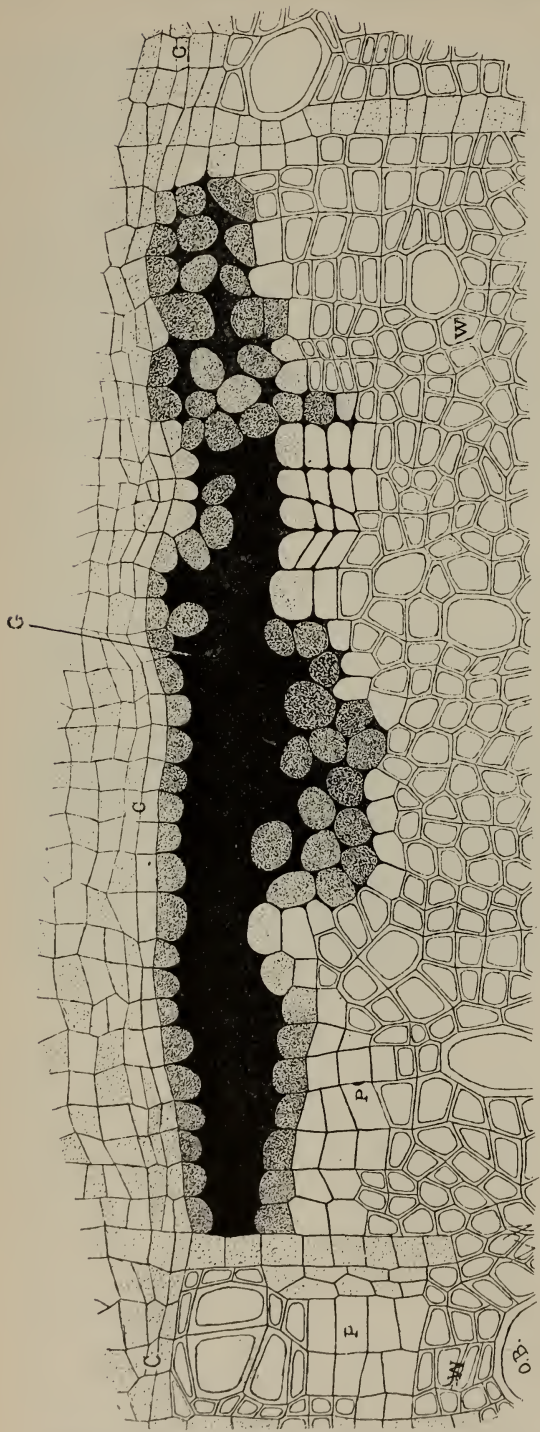

FIG. 4. Microscopic view of tissue affected by gum disease; an enlargement of area G in figure 1. W normal wood, PP regions of imperfectly formed wood, cell walls not thickened; C cambium, G gum pocket in new wood, just inside cambium.

thus in its chemical nature an unformed or soluble form of what should be the solid plant tissue. This gum accumulates, forming a pocket just under the cambium, or soon by pressure occupying the space between the bark and wood. Water also accumulates in this pocket, and finally, if the process continues, sufficient pressure is set up to rupture the bark and the gum escapes to the outside. The amount of gum depends upon the extent to which the changes described take place, as well as upon the amount of water in the tree. In severe cases large areas of the new wood are affected at many different points, and thus large or numerous gum pockets are formed, which results in separating a large area of bark from the wood. After the wound has thus been formed, infection, fermentation, or decay may set in, causing further injury to the tree, or an irritation may be produced by these factors, and the efforts of the tree to heal over the lesion may result in a continuation of the trouble after the original influence which caused the commencement of gumming has passed away.

This, in brief, describes the nature of the process of gum formation. It is in

many respects similar to the occurrence of an ulcer or boil in the human race, consisting in a failure of the formation of proper tissue at the affected point and the secondary effects of infection, putrefaction or other irritation.

METHODS OF CONTROL OF GUMMOSIS.

Avoid Unfavorable Conditions.—The most important consideration in regard to the control of gummosis is the fact that since the disease is brought about solely by unfavorable conditions it can be more easily prevented by avoiding those conditions than it can be cured after once started. By the same reasoning, the cure of the disease lies chiefly along the line of improvement of the conditions which have produced it rather than by any treatment of the tree itself. The avoidance of gum disease should be one of the chief considerations of the grower starting a citrus grove, particularly with lemons. In the choice of location heavy, wet ground should be avoided, unless it can be drained or improved in some manner.

Sour Orange Root.—On land which is otherwise desirable for planting, but has some qualities which would make it liable to gum disease, considerable immunity can be obtained by planting trees budded upon the Florida sour-stock root. We have made careful inquiry as to the success of trees upon this root in California, and find that there is ample experience to justify its use in heavy soils. The root has no advantage over the ordinary sweet seedling, except for the much greater freedom from gum disease which it imparts. Trees grown on the sour-stock are rather slow of development during the first few years, but bear abundant crops of fruit, and as time goes on they overtake those of the same age on sweet-stock, so that in mature trees there is practically no difference on the two roots. We strongly recommend the use of the sour-stock root for all citrus trees to be planted on heavy soil which is liable to gum disease.

High Budding.—Another important consideration for avoiding gum disease is high budding of the nursery stock. As we have previously shown, trees which are affected in the orchard usually have the point of budding deeply buried in the soil, and this condition contributes greatly to the disease. This may be easily avoided by budding the trees a foot from the ground, a practice which has no disadvantage except the somewhat longer time required to produce such a tree. Possibly an extra season may be necessary to get the young seedlings up to sufficient size to bud them at the desired height. The advantage gained, however, is much greater than this slight objection. Whether the trees are high-budded or not, care should be taken not to plant them too

deeply in the ground. Gum disease is induced in a great many young trees the first year in the orchard by planting them with the bud union

FIG. 5. High budded lemon tree; desirable to avoid gum disease.

below the surface, where they become covered with soil. This is extremely undesirable.

Cultural Prevention.—The prevention of gummosis in the orchard is entirely a matter of the avoidance of the conditions which have been shown to be the cause of the disease. The accumulation of soil or water about the trunks, allowing the same soil to become hardened, lack of drainage or cultivation, or the accumulation of surface water, either from irrigation or rain, must be carefully avoided. All these precautions are particularly necessary in places where the soil conditions are such as to favor the disease. In such places special care must be taken to keep the ground thoroughly stirred close up about the trunk of the trees and prevent either soil or water from accumulating about them. If this is accomplished one need have little fear of gummosis.

Improvement of Soil Conditions.—The treatment of affected trees must consist first of all in an improvement of soil conditions. It is idle to work upon the trees themselves or to look for any remedy for application to the affected parts until the original conditions which produce the trouble have been corrected. If this is not done, the work done upon the trees will be thrown away, since gummosis will begin again at the first favorable time. In treatment of affected trees one should therefore begin with a thorough stirring of the soil about the trees clear up to the trunks. It will, no doubt, be necessary to do much of this by hand with a mattock, but there is no other method of accomplishing the desired result. After thoroughly loosening up the soil a space of at least two feet in diameter must be cleared about the trunk, removing the accumulated soil down to the roots, exposing the bud union. In many cases a foot or more of washed-in soil will be found at this point.

Cutting the Bark.—After this has been done work may commence upon the tree itself to improve its condition. The bark of the tree where gumming has occurred may be cut out to some extent to relieve the pressure and permit the escape of the accumulated gum. In some cases the whole bark has been stripped off over all the affected portion, while in others only narrow strips of bark have been taken out, running from the crown up to the main fork on several sides of the tree. The latter process, on the whole, is thought to be the better method.

Stripping.—If the bark is stripped off entirely a large area is exposed on badly affected trees, and in some cases it is necessary to entirely girdle the tree. Under improved soil conditions much of this bark would be likely to recover and remain alive, or if it dies it serves to protect the trees and cover the new growth of bark, which often comes beneath it. Many cases, however, have been successfully treated by stripping off all the bark which showed discoloration beneath it, cutting out cleanly about the edges and painting over the exposed surface with

some protective covering. In such treatment the bark should be peeled off without scraping the surface of the wood, as often much of the cambium layer is still alive and will form a new layer of bark.

Treatment of Wounds.—For covering the exposed surface a form of grafting wax has been found most satisfactory. This is prepared by

FIG. 6. Lemon tree treated for gummosis by stripping off affected bark and covering with wax.

melting together 4 pounds of resin, 1 pound of beeswax, and 1 pound of raw linseed oil. After thoroughly mixing, the wax is painted on with a brush while still warm and liquid. In many cases a considerable amount of new bark can be seen forming under this transparent wax, and the tree makes a decided recovery. A great variety of other materials have been used for covering the wound, but none of them appear to be as satisfactory as the wax.

Slitting.—The method of slitting the bark, taking out one-eighth inch strips on four or five sides of the tree, through both the affected and the healthy parts, is usually most advisable. A special knife can be made for this work with which the slitting can be done quite rapidly.

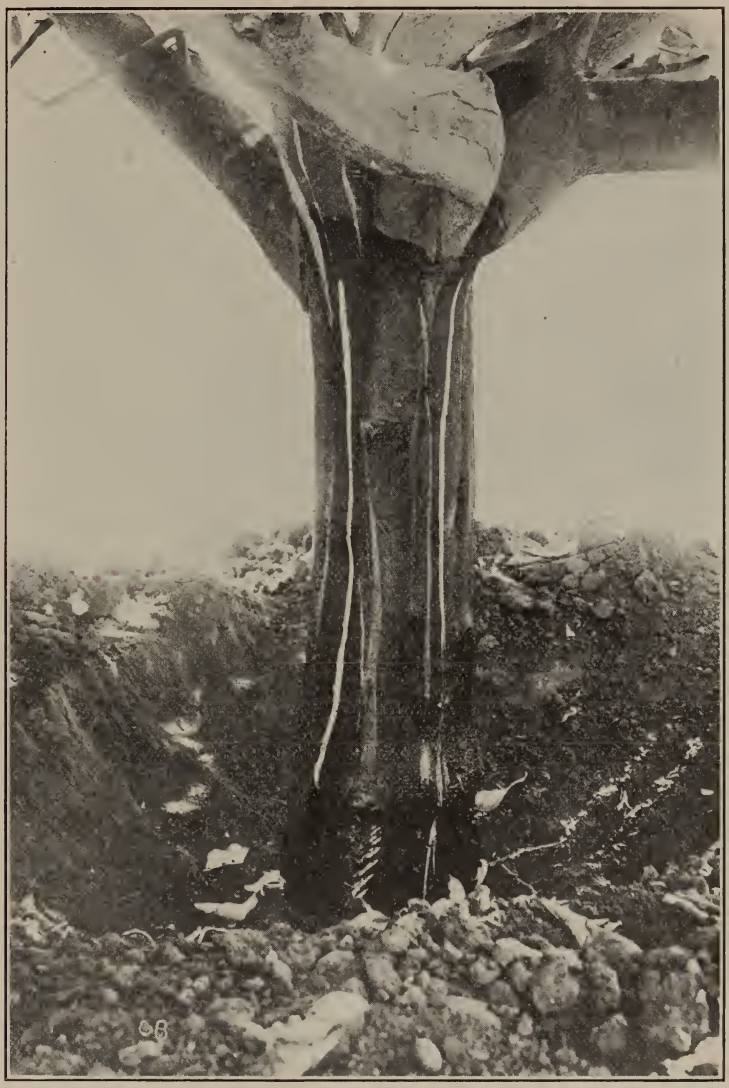

FIG. 7. Lemon tree treated for gummosis by slitting bark. Two whitest lines are new slits. Others are older ones. Note excavation about trunk.

Surface Applications.—After cutting the bark in this manner some application may be made to the surface, and for this purpose many different substances have been tried. The application of neat's-foot oil, recently recommended by Judge A. F. Call, of Corona, appears

quite effective, the oil tending to soften the bark and gum and keeping the latter from collecting in hard masses on the bark. A one-tenth solution of caustic potash in water has also been used with good results. Others have used crude carbolic acid, sheep dip, and a great variety

FIG. 8. Lemon tree pruned back after treatment for gummosis. Note excavation about trunk.

of other materials. The liquid substance recommended should be painted over the whole trunk of the tree, making a thorough application.

Soil Improvement Most Important.—The whole matter of the treatment of the tree itself is entirely of secondary importance. If proper soil conditions can be obtained and maintained, the tree will heal itself, if not too far gone. The only benefit to be derived from any method of bark cutting and surface application is to promote the healing of the wounds caused by the disease.

Pruning.—After treating the trunk of the tree it is well to cut back the top to some extent, reducing the amount of branches in proportion to the amount of bark lost from the trunk.

After the treatment of the soil and trees has been accomplished, measures must be taken to prevent as far as possible the recurrence of

FIG. 9. Lemon tree boxed at base after excavation and slitting bark.

the conditions which brought about the trouble. When possible to do so, the general level of the soil about the tree should be cut down so that the point of bud union will be well above ground.

Use of Sand About Trunk.—If it is impossible to do this, the hole which was dug out about the trunk must be kept open so that the soil will

not accumulate again at that point, and at the same time this hole must not be allowed to become a receptacle for irrigation and rain water, thus making the condition worse than ever. In such cases the practice of filling the space with coarse sand has been resorted to quite successfully, thus preventing the accumulation of water to quite an extent, and at the same time not producing a layer of hard soil about the trunk.

Boxing.—Another method consists in making a wooden box from one to two feet square about the tree with the sides high enough to keep out surface water. This is somewhat expensive, but is probably the best method that can be suggested for permanent improvement in cases where the trees are too low. In places where surface water accumulates, temporary open ditches may often be made to advantage during the winter to carry off the surplus.

Without further details, we will say, in general, that the whole prevention of gummosis consists in good drainage and proper aëration of the roots.

The following letter, recently written by Judge A. F. Call, of Corona, is well worth reproduction in this connection:

"I found on coming to California, early last year, that I had twelve hundred lemon trees out of three thousand more or less affected with gum, and four hundred orange trees out of sixteen thousand affected with so-called scab. After treatment for one year, all the gummed lemon trees, with the exception of four, have either fully recovered, or are well on their way to recovery, and now of a deep green color, well set with fruit, and all of the scabbed orange trees are showing marked improvement and on the way to recovery. I have made it a point to investigate these troubles in nearly every colony in California and several districts in Florida, and believe that I know the cause and cure for this trouble, and am satisfied that if drainage conditions will permit, these troubles can be prevented and trees that are not entirely gone can be cured.

"I came to the conclusion that this trouble was not a disease, but was simply a mechanical proposition, and to demonstrate this I inoculated several healthy trees by inserting chunks of gum under the bark, with the result that no tree was affected. On the other hand any injury to the bark will cause the gum to exude. This may be caused in a variety of ways. In some instances I found a small root encircling the trunk of the tree just above the crown roots, which had become imbedded in the bark and caused a stoppage of the flow of sap. In other cases I found that hard ground had buried some pebbles in the bark, with the same result. In other cases I found that hot manure around the trunk of the tree deteriorated the bark. In other cases, standing water around the trunk of the tree had injured the life of the bark, but by far the most common cause, and, in fact, perhaps ninety per cent of all the cases, is caused by earth around the trunk of the trees above the crown roots. As I look at it, the reason of this accumulation of earth affecting the bark is that the bark, which nature intended to be above the ground, is more tender than the bark on the root, which nature intended to be below ground, and becomes easily affected, when deprived of air and in contact with the earth, especially wet earth.

"The gum disease of the lemon trees and the scab disease of the orange trees is substantially the same trouble, and comes from the same cause, and that is an injury to or deterioration of the bark of the tree which impedes the downward flow of sap. I believe an examination will show a darkened or deteriorated condition of the bark somewhere on the trunk of the tree below the point where the gum is exuding.

"The treatment should commence with the removal of the cause, and that is by removing the earth down to the crown roots and giving the tree proper drainage. This should be done very carefully, as there is danger that the hoe or shovel of the workman will bruise or cut the crown roots and thus cause additional trouble. When the earth has been removed, that portion of the trunk which has been covered with earth should be whitewashed, to prevent injury caused by sudden exposure to the air and sun. The next thing to do is to split the bark to permit the escape of the surplus sap, to prevent its accumulation and consequent destruction of the bark. This should be done by making a narrow furrow from one sixteenth to one eighth of an inch in width from the limbs to the ground. About four of these furrows are usually sufficient at about equal distances apart.

"It is a great mistake to make several short gashes around the bud, as is frequently done, for this brings the surplus sap all to one point and causes a greater injury. It is also a mistake to remove the bark, as is frequently done, which is supposed to be affected, for this causes a big wound which it takes a long time to cure, and my experience has shown that the largest part of the bark which appears to be affected will recover when the cause is removed and the surplus sap permitted to escape. After this is done all the affected portions and furrows through the bark should be thoroughly covered with neat's-foot oil. There is a double advantage in the application of this oil. One is, that it has a softening effect on the bark and aids in restoring its sap-carrying power. The other is, that it prevents the gum from sticking to and hardening on the bark and facilitates the removal of the gum, which will flow from the furrows.

"After the trees have been treated they should be carefully watched, and two or three weeks after the first treatment they should be gone over again, and gum removed from the furrows, with a second application of the oil, and this watchfulness and care should be continued until the gum has ceased to form.

"It will be found that at the end of the year all the trees not badly affected will have recovered, and those which have been affected over considerable area will show some affection just above the old scars, owing to the injury of the bark still existing, with not enough new growth to carry all the sap. Most of the trees carrying a large amount of sap may have been so badly affected that there is not sufficient amount of bark left to carry so much. When this condition is found, or, in fact, wherever the tree is more than half girdled or more than half of the bark is seriously affected or dead, the top should be cut back in proportion to the injured bark—that is, if one half of the bark has been destroyed, one half of the top should be removed. If only a strip two inches wide of good bark remains, but a very small top should be left.

"Last year I had one tree with a trunk about six inches in diameter, that only had left a strip of bark one inch in width. I cut the top of this tree severely. Now that strip is three inches in width, the top has grown vigorously, the tree is full of fruit.

"I believe that any one having a grove showing gum should not wait for it to develop, but should prevent it by carefully removing all the earth to the crown roots, and most growers will be astonished to find how deep their trees are in the ground. This is partly caused by original deep setting, partially by plowing the earth to the trunk of the tree and leaving it there, and partially by sediment carried from the upper end of the grove to the lower and there stopped by a dike or head ditch.

"After the earth has been removed, it is important to prevent a basin for water being formed, and therefore the excavation should not extend more than a foot from the trunk of the tree. The trees that are very deep should be boxed with a box about two feet square, extending above the ground. The trees that are not so deep should be filled with loose sand or gravel, as this will permit some aëration and will not cause the disease that a hard or wet earth will cause.

"In making the furrows in the trees I had a little tool made which is much better than a knife, by taking a thin bladed blacksmith's knife and having the blacksmith bend it in the middle to a sharp angle and then sharpen it. It will cut a furrow about one sixteenth of an inch wide and avoid the danger of gashing or haggling the tree, which might be done by a careless workman with a knife."

SCALY BARK, OR PSOROSIS.

This is primarily a disease of the orange. While its occurrence on other citrus trees may not be unknown, it is certainly extremely rare in

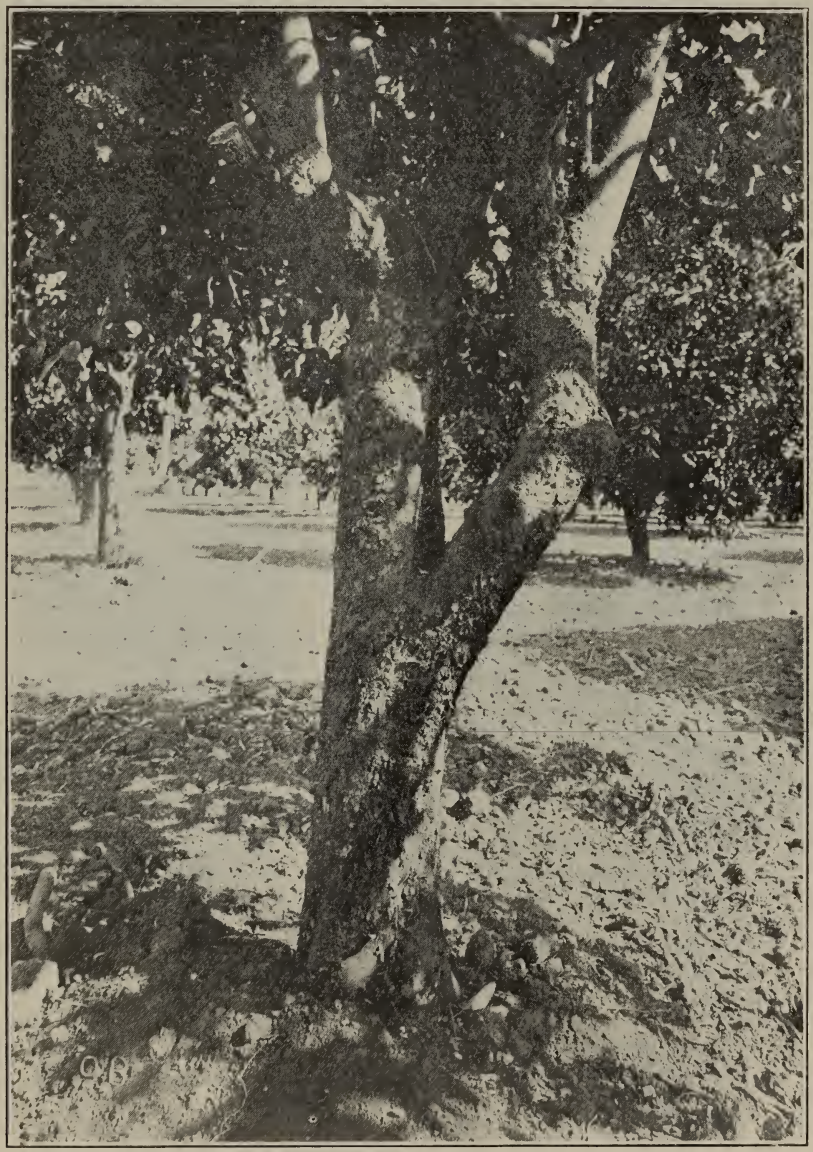

FIG. 10. Orange tree affected with scaly bark.

a typical form. Scaly bark is distinguished particularly from gummosis by its occurrence at any point upon the branches or trunk of a tree, with no apparent direct connection between the soil and the location of the affected area. Also by the scaling off in flakes of the outer bark,

leaving the inner layer nearly intact, instead of a separation between wood and bark, as in gummosis. Most commonly the disease appears first upon the trunk, although often at a considerable distance from the ground in large trees, but it commonly breaks out in isolated spots upon the branches, even upon those of quite small size.

The appearance of the disease is suggested by its popular name. At

FIG. 11. Scaly bark area on orange limb.

a certain point on the trunk or branch the surface layer of bark begins to break out in scales which curl up and separate from the inner bark. This separation of the bark into scales does not occur at the cambium layer between the bark and wood, but involves simply the outer rough bark. The inner bark remains in its proper position and becomes more or less pushed out as the disease progresses, owing to the irregular growth of the wood beneath. The scaly portion is usually only an inch

or two in diameter at first, but gradually spreads until it covers a large patch, or may involve the whole surface of the trunk and much of that of the limbs. There is no very abundant production of gum from the affected portions, but here and there a small pustule breaks out from which gum exudes of a similar nature to that seen in gummosis. The gum is less abundant than in the latter disease. Trees affected with scaly bark soon lose their healthy appearance as the disease develops, the foliage becomes sparse and light colored, and the branches die back so that the top of the tree becomes full of dead wood. Such trees, however, seldom die completely, but linger for many years, throwing out new shoots from the trunk and maintaining a feeble existence. Scaly bark is most commonly seen on old trees rather than young ones, and is especially common in some of our old seedling orchards or the oldest groves of the Washington Navel.

Relation to Soil.—The occurrence of this disease with reference to any particular condition of soil, cultivation, or climate is rather less evident than in the case of gummosis. It has no pronounced relation as in the latter case to heavy soils or excess of moisture, or at least not in the evident manner which is seen in the other diseases.

Becomes Chronic.—One feature of scaly bark which makes the determination of the causes which bring it about quite difficult is the fact that in the majority of cases affected trees have been in their present condition for a great many years. The disease shows no rapid spread or greatly increased prevalence, but so far as can be learned has been in much the same condition as at present for a long time. Many trees can be identified which have been affected for at least fifteen years, and while their appearance is very bad, it would seem from what can be learned that their condition has changed very little during this period. In the majority of cases the trees in an orchard affected by the scaly bark are scattered indiscriminately about, with no decided relation to each other or to any particular condition.*

Related to Irregular Water Supply.—So far as can be learned from a large amount of field observation it would seem that scaly bark is connected, more than with any other condition, with one of extreme changes in the moisture condition of the soil. In other words, where the soil, together with the roots of the tree, becomes alternately very wet and very dry.

This is brought out to a considerable extent by a microscopic examination of the wood of orange trees affected by scaly bark. In ordinary deciduous trees the growth is commonly divided into two periods each year: one of activity and one of rest. During the growing portion of

* See page 240.

the season, that is, in the summer, a ring of wood is formed and the number of these rings corresponds to the age of the tree. In the citrus tree there is no such annual growth, but a more or less continual development all the year round. The wood of an orange tree grown under good cultivation with a uniform condition of moisture, never too wet or too dry, has a very uniform structure with only a slight indication of ring formation. The wood of a scaly bark tree, on the other hand, always shows very evident rings, corresponding not to years but to periods of growth, of which several occur during the same year. The more irregular the conditions of growth the more prominent are the rings, and in neglected trees which are watered irregularly the ring formation is more marked, compared with those which are well cared for. This being particularly true in scaly bark trees shows that their growth has been irregular rather than uniform.

If it be asked why trees which are uniformly irrigated still show scaly bark, it should be remembered here again that the majority of those now affected have been in this condition for many years, and the conditions which brought about the disease may have totally changed. The effect on the tree once begun may remain and continue to spread long after the original cause has passed away.

In a number of pronounced cases of scaly bark in somewhat neglected or poorly-cared-for orchards, we have found the principal area of affected trees to be situated near the flumes or source of water supply. This is particularly true over hardpan, or where by shallow cultivation an artificial hardpan has been formed. In such places the soil becomes very wet during irrigation and very dry between times. To this condition may be ascribed many of the most pronounced cases of scaly bark.

Further than this we have seen orchards containing areas of this disease where no improper conditions are now present, but where it is stated that in former times the water was accustomed to settle or accumulate during the irrigation by the flooding method then in vogue. Other cases of scaly bark in individual trees have seemed to show connection with a deep burying of the roots, the planting of a tree over a boulder or area of hard soil, or some other circumstance which would bring about the condition described.

It is our opinion that a large majority of the present cases of disease, affecting isolated, scattering trees in groves where no unfavorable conditions can be detected, are relics of a former period of cultural or irrigation practice different from that now in vogue. The reason why individual trees, rather than the whole grove, were affected has already been attributed to differences in individuality and possibly also to varying soil conditions immediately underlying the trees.

An Extreme Case.—We have known of one instance where scaly bark was brought on in an almost epidemic manner by a radical treatment of an orchard. In this case, of some large seedlings, the grove was very much neglected as to irrigation and cultivation for a season, and was finally pastured with cattle. In this way the ground became very dry and hard packed. During the following winter, in a spasmodic effort at improvement, a large stream of water was turned into the grove and the whole surface completely flooded and the ground thoroughly saturated. Following this treatment scaly bark appeared upon several hundred of the trees in such a manner that one could scarcely doubt the connection of the disease with this radical treatment. Further, it may be said that by subsequent good cultivation and uniform irrigation most of the trees recovered and came back into good condition.

Relation to Gummosis.—Not unfrequently cases occur of forms of disease intermediate between scaly bark and gummosis. In these the eruption occurs upon the trunk with a scaling off of the bark to a greater or less extent, and an exudation of gum in a manner resembling that in both of the typical diseases to a certain extent. In fact, all gradations may be found between the two diseases. Scaly bark has all the appearance of a mild form of gummosis, affecting the tree somewhat differently on acount of differences in conditions, but much the same disease in regard to its real nature. The fact just mentioned, that forms intermediate between the two diseases can be found, goes far to prove this, and further evidence is obtained by a study of the affected tissues.

The condition as to the formation of the gum is practically the same in both diseases, the only difference being that in the more active gummosis considerable areas of bark are ruptured from the wood, while in scaly bark the gumming is less active and breaks out only rarely to the surface, the slight irritation set up causing an abnormal growth of wood and the scaling of the outer bark. The effect is so slight that the growth of the wood and bark at the affected point continues for many years, the wood being discolored and poorly formed on account of the numerous gum pockets which it contains, and the bark, rough, scaly, warty, and impregnated to some extent with the dried resinous gum. The presence of the scaly area keeps up an irritation which extends, rather than allowing the healing of the wound.

The origin of the gum is the same in scaly bark as in gummosis, but the effect on the tissues is somewhat different. In scaly bark the abnormal process is less active, so that wood formation over the gum area is quickly resumed. This results in the continual formation of poorly developed wood containing numerous gum pockets and warty projections which push out the bark and cause the typical scale formation. Scaly bark, therefore, as well as gummosis, is a disease of the

wood rather than one of the bark, the effect on the latter being entirely secondary. The wood of scaly bark trees is discolored beneath the affected areas, extending often far into the trunk or branch. This discoloration seems to spread inward to some extent in wood which

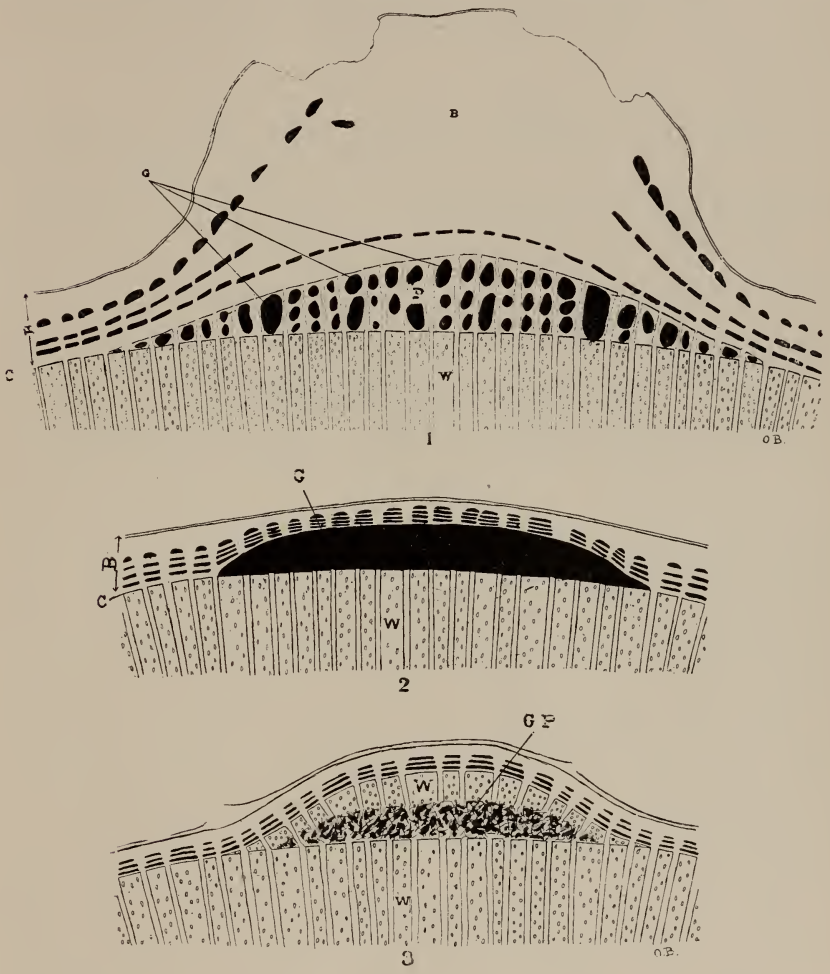

FIG. 12. Schematic sections of affected stems in 1, Exanthema; 2, Gummosis; 3, Scaly Bark. W normal wood, C cambium, B bark, G gum, P imperfect wood. In 3, Scaly Bark, normal wood is seen again outside the gum pocket, forming a projection and causing a pushing out and scaling of the bark. The gumming region is composed of a mixture of gum and poorly formed wood. In 2, Gummosis, a solid mass of gum is seen between the wood and bark. In 1, Exanthema, the pustule is composed largely of bark tissue, overlying masses of abnormal wood in which are embedded numerous gum pockets.

had previously been healthy, but is usually, if not always, a result of the growth of the tree. The disease is not severe enough to kill the tissue entirely at the affected places, so that the formation of new wood goes on to some extent, and this wood is diseased and discolored by

gum pockets, and after a number of years may have considerable thickness under the scaly bark spots.

The influences which determine the point on the tree where scaly bark may break out have been already alluded to on page 240. Of particular influence is probably the irregular growth and poor development of the wood under uneven moisture conditions affecting the flow of sap.

Relation to Florida Diseases.—The California scaly bark disease would seem to be identical with the trouble mentioned by Swingle and Webber* as occurring in Florida, and called by them *Psorosis*. They speak of this disease as follows "Psorosis, the disease known in Florida as 'tears' or 'gum disease,' is often confounded with foot-rot, but is unquestionably quite distinct. In appearance it is similar to foot-rot, but with it the diseased spots occur on the limbs and occasionally on the trunk, but never on the roots, so far as known. Psorosis does not kill the bark entirely, but extends only to the middle layer, the inner bark and cambium layer remaining healthy." In the annual report of the Florida Experiment Station for the year ending June 30, 1907, two diseases are described, either one of which might be identical with our scaly bark. The one described on page 43 under this same name and illustrated in plate 7 appears much the same, except that a spotting of the fruit is described as a symptom of the disease, which is not the case in California. On page 46 of the same report a disease is described under the name of "Gumming of Citrus," which also appears to have much in common with our disease: "The gumming areas are usually at a considerable distance from the ground on the trunk and larger limbs. This point of difference distinguishes this from the foot-rot. The trunk cracks and gum oozes out in considerable quantities. New bark tissue is formed underneath the old. The surface of the area becomes characterized by ridges, warts, and resinous deposits. Finally the bark dies and the wood slowly decays inward." This disease evidently is closely related to one or the other of the forms occurring in California. No cause is ascribed either to this or that described by Swingle and Webber. The disease described as "scaly bark" in the Florida report is thought to be infectious, and is said to cause a serious dropping of the fruit as well as the spotting already mentioned.

CONTROL OF SCALY BARK.

The treatment of trees badly affected with scaly bark is not a promising undertaking. When far advanced the condition becomes one of such a chronic nature that a satisfactory cure is almost out of the question. A general survey of the occurrence of this trouble in Cali-

* The Principal Diseases of Citrus Fruits in Florida, Bull. 8, Div. Veg. Phys. and Path., U. S. Dept. of Agr. 1896.

fornia makes evident the fact that the prevention of this disease is much more to be sought after than methods of treatment for its cure. Scaly bark is not a disease of common occurrence in our best orchards. While occasionally a tree may be affected even in some of the finest groves, yet such cases occur very largely where the soil is of uneven quality, and more often scaly bark accompanies poor culture, unfavorable soil conditions, or neglect. In a great many groves, as we have already mentioned, where the present methods of culture are good, the scaly bark trees are a relic of former trouble and have been in their present condition for many years.

The prevention of scaly bark appears to be best accomplished by the maintenance of uniformity in regard to moisture conditions. It is scarcely necessary to go into methods of accomplishing this in this publication, but according to the nature of the soil and other conditions the grower must endeavor to maintain uniform moisture rather than to allow the soil to become alternately wet and dry. Frequent examination of the soil by digging to a considerable depth in different parts of the orchard will be found a most profitable practice when there is any uncertainty as to the moisture condition.

Treatment of Affected Trees.—The individual treatment of affected trees may proceed on much the same lines as that described for gummosis. It is useless, however, to attempt to cut out or strip off the affected bark if the disease is far advanced. When the scaly areas are still small they may be cut out, taking care to cut all the discolored tissue around the edges, particularly at the upper end. The wound may then be covered with the wax previously described. Where large areas of scaly bark exist on the tree it is useless to try to cut them out and in most cases it is practically impossible to do anything for permanent benefit. If the condition is not too bad, the scaly areas may be scraped to take off the rough bark, leaving the green inner bark, most of which is alive. A few slits may be cut through this to allow the escape of the gum and the place then painted over with some softening substance, such as a one-tenth solution of potash or neat's-foot oil, as previously mentioned. The worst affected trees may profitably be pulled out and new ones planted in their places, after first working over the soil deeply to make sure that no injurious condition, such as hardpan or large rocks, exists at that point. Frequently an affected tree can be cut off near the ground below the scaly bark areas, and upon the sprouts which come up buds can be inserted and a new tree can be obtained more quickly than by replanting. If these sprouts come from above the original point of budding no rebudding will of course be necessary.

GUMMING OF NURSERY TREES.

It is quite a common occurrence for young citrus trees to be affected with a form of gum disease either in the nursery or immediately after planting in the orchard. This trouble consists in a breaking out of gum at different points on the tree, which gum may be easily seen to originate from beneath the bark, breaking out through ruptures to the surface. If the gumming occurs soon after the trees have been pruned or cut in any way it usually appears at the point where the cuts have been made. Gumming very frequently takes place at the point where the cut in the bark is made for budding, and in some seasons a considerable loss of buds is experienced in this way, both in the nursery and in older trees which are being top-worked. This takes place particularly in seasons of abundant rainfall in the spring. Other cases occur with young trees where the gum appears beneath the forks and crotches, at the junction between one growth and another, or at any point where the flow of sap is somewhat interfered with. This trouble almost always occurs under the conditions just mentioned as to rainfall, or where the trees have been heavily irrigated and the water allowed to stand close about them, on trees planted in very heavy soil and often where the trees are planted too deeply with the bud union covered to some depth. The whole matter of gumming of young trees is indeed quite an obvious case of cause and effect, illustrating the relation between citrus gumming and an excess of water, depth of planting or mechanical injury. A large number of trees show more or less gumming during the first year in the orchard, but usually without serious consequences if they are properly attended to as to depth of planting and moisture or drainage conditions, unless they have been too badly affected to recover. Some trees which were affected in the nursery may continue to gum in the orchard, even under good conditions. If well taken care of they will usually recover.

Control of Gum Disease in Young Trees.—In the nursery gum disease is almost always caused by too much water close about the trees. When due to rainfall this can not always be avoided, but the choice of location for the nursery should be one of good drainage and not too heavy soil. In irrigation the water should not be allowed to flood the trees. If the trees become affected in the nursery they should be kept particularly well cultivated so that there is no packing of the soil about them, the soil should be kept from burying the trees above the proper depth, and particular pains must be taken to prevent water from standing about them.

When young trees in the orchard show gumming, the same treatment should be given and the same precautions exercised. In case the trees

gum when everything seems all right in these respects they may be still showing the effects of disease contracted in the nursery, and recover of themselves, without any treatment. If a considerable amount of gumming occurs on the trunk of the young tree it is advisable to relieve this condition somewhat by slitting the bark in a few places, as previously described. In young trees it is not advisable to strip off the whole bark at the gummed places, as some of it is still alive and might recover. It is better to plant a new tree than to start with one having a large amount of bark removed.

The desirability of high-budded nursery trees has already been discussed, and the general course of treatment given on page 247 applies here as well.

FOOT-ROT.

The true foot-rot, as described in Florida and many foreign countries, is not of common occurrence in California, where the ordinary forms of gum disease are evidently of a somewhat different nature. The latter particularly do not show a decay of the roots, a rotting of the bark or any effect whatever below the surface of the ground. The Florida disease is decidedly different in this respect. A few cases of true foot-rot have been found in this State, and these agree perfectly with the conditions described elsewhere. In some instances the roots were badly decayed from the surface of the ground downward, even before the top of the tree showed a very serious condition. The decay starts in the bark, which becomes soft and rotten, spreading all over the main roots until finally the tree dies. There is no gumming on the sides of the trunk as in the disease which we have described as gummosis. The odor of the affected bark is disagreeable and quite characteristic.

In the cases of foot-rot found in this State the affected trees were invariably growing under conditions of extremely poor drainage and very wet, heavy soil about the roots. As the same condition is said to exist in other countries where this disease prevails, it would appear to bear considerable relation to the other forms of gum disease described. From the accounts of this disease in many countries it would appear that it has broken out in an epidemic form, spreading rapidly through the citrus districts and causing widespread destruction of groves on all kinds of soil. For this reason it has sometimes been thought to be caused by an active parasite rather than to be simply the result of unfavorable conditions. No such parasite has been identified, however, as the cause of the disease by the many investigators who have studied it, and the conclusion is quite general that its relation to soil and moisture conditions is the most important consideration in regard to its origin. Certainly in California the cause of this trouble seems

to be very plainly an extremely heavy, wet condition of the soil, and the disease has shown no evidence of spreading by infection.

Control of Foot-rot.—The control of foot-rot, as it occurs in this State, is obviously a matter of improvement in drainage conditions. Most of what has been said in regard to gummosis applies equally well here. Affected trees may be treated to some extent by the methods described.

FLORIDA DIE-BACK, OR EXANTHEMA.

The disease described under this name by Swingle and Webber (*loc. cit.*) undoubtedly exists in California to a limited extent. Its occurrence, however, is so manifestly connected with certain soil conditions that a general spread of the disease is not to be feared. In fact, it is evident that this trouble has occurred in California for many years, since it is described by Mills in Bulletin 138 of the California Experiment Station, issued in 1902. The disease is a very characteristic one, and is in many ways quite different from the other forms of gum disease described, but akin to them in the production of gum from the diseased parts and in other ways which we shall show later.

FIG. 13. Exanthema on orange twigs, showing bark pustules.

The most prominent characteristic of exanthema is the occurrence of numerous swellings or pustules on the bark of the smaller branches and twigs. These swellings are very numerous, and in bad cases the twigs and branches are completely covered with them. In many of the eruptions gum pockets are formed in the wood, and the resinous gum exudes and hardens on the outside.

Another feature of the disease is the formation of a large number of shoots from the axils of the twigs, which grow out in a bushy manner but soon die. The ordinary foliage of trees affected with exanthema does not appear sickly, but rather the opposite. The leaves become abnormally large and of a very dark green color, giving a deceptive appearance of health. In the fruit of affected orange trees extremely characteristic symptoms of exanthema are found. The normally green color of the unripe orange becomes pale and unhealthy looking, and develops as the fruit matures into a peculiar lemon yellow or dull, yellowish green, quite different from any color ever seen in healthy fruit. The oranges thus affected become stained with a brown, gummy exudation occurring in patches on the rind. At these places the fruit usually splits and finally falls from the tree before reaching maturity. This effect on the fruit appears to be one of the first indications of the disease in California, occurring sometimes without any of the symptoms mentioned on the twigs, and taking place one year with no indication of the disease whatever during the following season. This happens only in the regions to which the typical occurrence of the disease is confined. The affected fruit has very little acidity, even when small and immature, but an insipid sweetness long before its natural time of ripening. The staining of the fruit is caused by a deposit of a gummy substance in the cells of the epidermis.

FIG. 14. Exanthema, showing dead, bushy growth.

Relation to Soil.—The occurrence of exanthema in southern California is limited almost absolutely to groves on the very porous, granitic, rocky type of soil which occurs close to the base of the mountains in some districts. Under such conditions the disease is prevalent and abundant, and nowhere else. Its only occurrence beyond this has been in a very few isolated instances.

Relation to Fertilization.—The cause of exanthema is thought in Florida to be the excessive use of organic nitrogenous fertilizers. The injudicious application of materials of this sort is said to be commonly followed by the appearance of the disease. To the same cause may be ascribed the occurrence of exanthema in California in the few isolated cases mentioned, not on the type of soil described as showing the most of the trouble. In these individual cases excessively heavy applications of sheep manure or other organic material had been made and the typical disease resulted. It may also be said that after this practice was stopped the trouble disappeared. On the soil where exanthema is most common no excessive amount of fertilizer of any sort can be considered the cause of the trouble. It is true, however, that to a considerable extent the disease appears upon trees which have received a fair amount of plant food, while trees upon the same soil which have not been well nourished show ordinary die-back and starvation, but not the characteristic exanthema. Experience is also reported upon this soil that the spasmodic application of considerable amounts of stable manure has produced the symptoms of the disease in the fruit even when the trees were not badly affected.

Cause.—It seems most probable that the occurrence of exanthema almost exclusively upon this type of soil is connected with the irregularity in the food and moisture conditions to which the trees are subjected. During irrigation the extreme looseness of the soil makes the water and its dissolved mineral salts freely available to the roots, and the movement of soil water and salts is very free. Unless the moisture condition of the soil is very closely watched, however, it is likely to dry out rapidly and there is also very little lateral penetration from the irrigation furrows. The whole condition is one likely to produce extremely irregular nutrition of the tree, unless very carefully handled. It would seem that in this factor lies the reason for the occurrence of exanthema upon this soil. Manifestly a very careful attention to the maintenance of uniform moisture and fertility is most important in the control of the disease, and this in actual practice has proven to be the case.

Very large amounts of organic fertilizing materials, such as blood or stable manure, must be used cautiously in view of this disease, yet at the same time the type of soil on which the trouble is most common is particularly in need of just such material. The whole trend of the logical handling of this soil is along the line of increased organic matter in order to increase the water-retaining capacity and thus promote uniform growth. Without the addition of considerable amounts of such material in the form of manure and green manure crops, it is most difficult to maintain uniform moisture conditions, while at the

same time supplementary applications of commercial fertilizer are necessary for the sake of plant food.

For avoiding exanthema on these coarse, rocky soils, as well as for successful citrus production in general in the same locality, the object must be to increase the organic matter and thereby the water-holding capacity of the soil by the use of stable manure and green manure crops, to feed the trees liberally, particularly with nitrogen and phosphoric acid, and at the same time keep the soil uniformly moist by careful attention to the methods of irrigation and cultivation practiced.

The condition which tends most to produce the disease is that of extreme dryness between irrigations, which often occurs in this soil. This is due to the extreme porosity, causing the water to quickly sink downward and leach away, accompanied by rapid evaporation from the surface. To wet this soil uniformly and keep it moist the runs of water must be short, the irrigations frequent and abundant, and the furrows numerous and covering the whole surface of the ground. Long runs of water, few furrows, and wide spaces between them and scanty applications are to be particularly avoided. Frequent examination by digging will readily show the moisture condition of the soil.

The prominent formation in the wood of rings of growth, mentioned in connection with scaly bark, is even more marked and very striking in exanthema, pointing to the same condition of irregular growth.

Effect of Spraying.—Considerable discussion has been provoked concerning the alleged cure or improvement of trees affected with exanthema by spraying the foliage with Bordeaux mixture. The results particularly of such spraying carried on in the vicinity of West Highlands by Mr. D. W. Divine point strongly to decided improvement in the condition of the trees. From the well known physiological action of Bordeaux mixture upon foliage, aside from its effect as a fungicide, and the apparent nature of the disease as described above, it is not irrational to attribute the beneficial results claimed to the action of the spray. It has frequently been shown that the action of the mixture on foliage is to increase and stimulate assimilation, producing decidedly beneficial results in this way, even on healthy plants not attacked by any parasite or disease. This being the case it is not improbable that Bordeaux mixture applied to the leaves of orange trees affected by exanthema acts as a stimulant to the nutritive processes and thus counteracts the injurious tendencies of the conditions described. For permanent benefit, however, it is necessary to pay the strictest attention to obtaining the best possible cultural conditions before resorting to spraying or any similar expedient.

TWIG BLIGHT.

A condition occasionally occurs on orange trees in California which may be designated by this name. This is seen as a sudden dying and withering of small terminal twigs here and there in the tree which had hitherto appeared entirely healthy and normal. The green leaves suddenly wither and remain attached to the twig, which dies back for a short distance, and with its dead leaves shows very prominently in the green foliage of the tree. Usually only small twigs are affected and the appearance is as though they had been broken and remained hanging. At the point to which the twig dies back a few drops of gum appear and harden. This trouble is by no means a serious or important one and need not be apprehended in the least where it occurs. It is quite a common occurrence, but never results seriously. No apparent cause can be seen for the death of the twigs in this manner, but the production of gum would indicate an interference with the flow of sap for some reason.

CITRUS GUMMING IN GENERAL.

As may be seen from the description of the diseases given above, the production of gum is the almost constant accompaniment of any injury to or interference with the functions of the citrus tree. Beside the cases mentioned others might be described where gumming occurs, but those given are the most characteristic.

Orange Splitting.—In the splitting of oranges, particularly the Navel, which is so abundant and destructive some seasons, a drop of hardened gum is invariably found just at the spot where the split in the tissue occurs. Whether this accumulation of gum is a cause or effect of the splitting is difficult to determine. Indeed, in many oranges which do not split, but mature normally, drops of hardened gum can be found at the blossom end. The same is seen regularly in the saucer peach, grown commonly in southern California.

Leaf Gumming.—The leaves of oranges and other citrus trees often show a form of gumming, but not as an indication of any particular disease. In many cases, indeed, trees with such leaves are to all appearances entirely healthy. This gumming takes the form of a brown solid deposit in spots or pustules just beneath the surface. Trees which are affected with any injurious condition are likely to show this effect in the leaves, but, as just said, it is not always an indication of any trouble.

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